SANTA CLARA VALLEY WATER DISTRICT

Highway Safety Road Flare Contamination in Storm Water Runoff Migrating to Lexington Reservoir.

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Executive Summary

The potential impact of non-point source pollution from highway runoff containing highway safety road flare components, specifically perchlorate migrating to the Lexington Reservoir was the objective of this evaluation. Potassium perchlorate is used in the production of highway safety road flares, which are commonly used on Highway 17 as a means of providing safety awareness to commuters and redirecting traffic.

The research reported herein was a study designed to evaluate the potential of perchlorate in flares to migrate with runoff flowing along and adjacent to Highway 17 and into engineered and natural channels which eventually flow into the reservoir. Laboratory tests conducted by the District in 2003 showed that in theory a single 20 minute flare could potentially contaminate up to 1.46 acre-feet of water to just above the State notification level of 6 micro-grams per liter (μg/L).

In order to evaluate the potential for these road flares to contaminate the reservoir, accident reports for the stretch of Highway 17 next to the reservoir as provided by the California Highway Patrol (CHP) were studied, and telephone interviews were conducted with CHP personnel on flare usage procedures. Drainage plans and drainage operating procedures for the highway were obtained from California Department of Transportation (Caltrans). The major findings are summarized below:

- Analysis of flare usage and rainfall runoff carrying flare components along Highway 17 and into the Lexington Reservoir appears to indicate that there is a minimal threat of perchlorate levels reaching the notification level limit establish by the State of California in the waters of the reservoir.

- Although reported accidents for this stretch of the highway are documented, due to the lack of a flare usage protocol per accident by the CHP, it is difficult to accurately determine how many actual flares are used in a given period.

- Reservoir water levels in the fall and winter make it vulnerable to contamination from roadway runoff during the first flush of the season. Other studies have shown that water bodies in the proximity of roads are typically impacted with oil, suspended solids, metals, hydrocarbons and other organics.

- Due to the uncertainty of what effects any perchlorate concentrations in runoff from the highway can have on the local creeks where runoff flows to, taking water samples during the first flush of the season at varied locations and in particular at the detention basin constructed by Caltrans in the area, would help determine if perchlorate presents any threat to the reservoir. As an added benefit, other common contaminants such as oil, suspended solids, metals, hydrocarbons and other organics could be monitored on a regular basis, while monitoring the water quality and aggressively protecting the surface and groundwater supplies.

Highway Safety Road Flare Contamination in Storm Water Runoff Migrating to Lexington Reservoir.

Objective

The objective of this study was to evaluate the potential impact of non-point source pollution from highway runoff containing highway safety road flare components, specifically perchlorate migrating to the Lexington Reservoir.

Background

Flares and Perchlorate

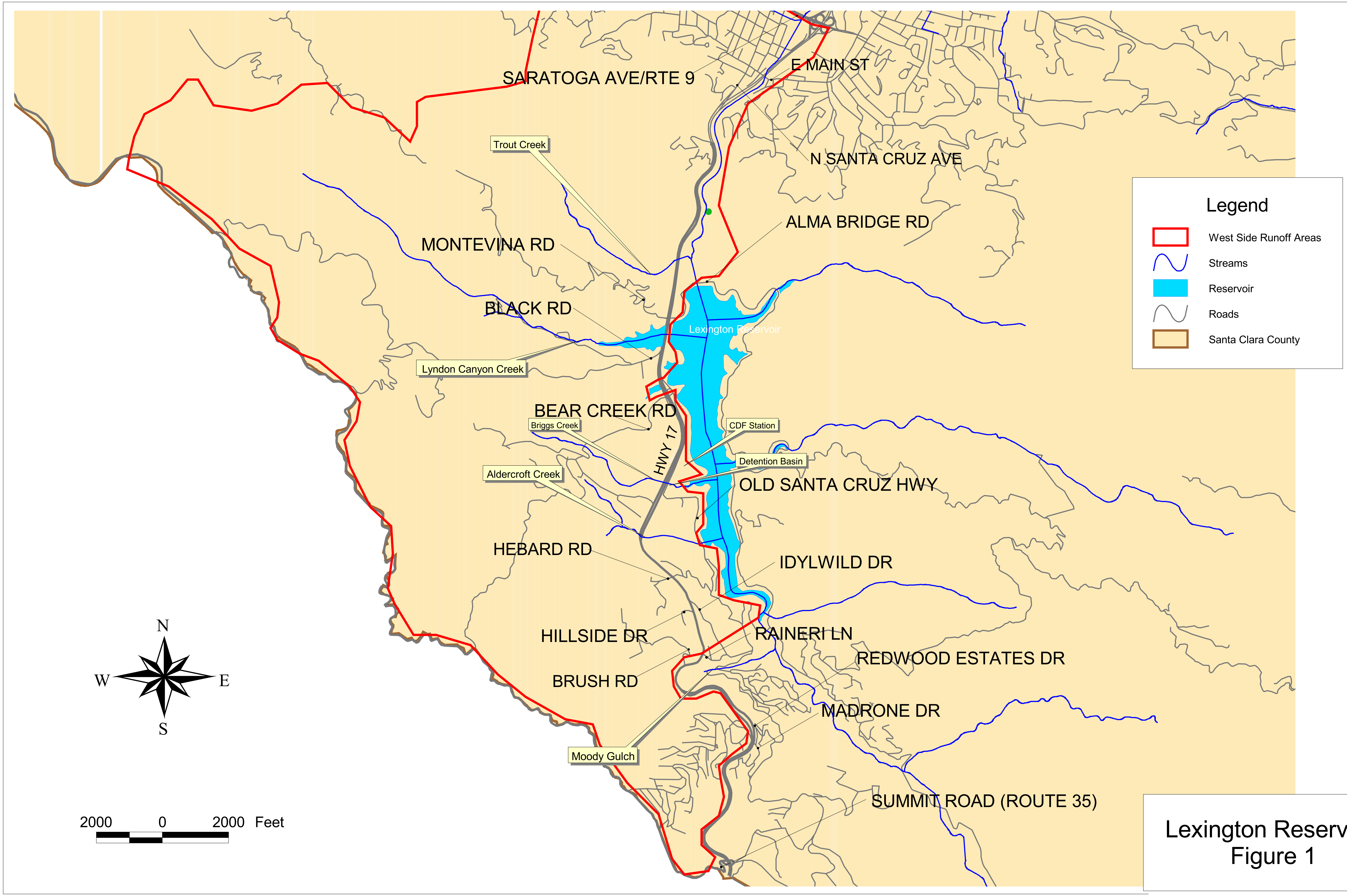
Highway safety road flares (flares) are used primarily to warn oncoming motorists to steer clear of accidents, stranded vehicles, or hazards on the highways. A primary component of flares is potassium perchlorate ($KCLO_4$) along with other components such as strontium nitrate, sulfur, sawdust and oil, and others in smaller quantities. Perchlorate salts are soluble in water and are considered strong oxidizing solutions.

The Perchlorate anion (CLO_4^-) is believed to interfere with the iodine uptake by the thyroid gland. The result of ingesting this inorganic contaminant is decreased production of thyroid hormones, which are needed for prenatal and postnatal growth and development, as well as normal metabolism and mental function in an adult.

Lexington Reservoir and Highway 17

Lexington reservoir is located just east of a two-mile stretch of Highway 17 in the Santa Clara County, south of San Jose (Figure 1). Topography is mainly mountainous with sections of relatively gentle slopes. Highway 17 is a main corridor connecting the Santa Clara County with the Santa Cruz Mountains and coastal cities to the west. Heavy car congestion is common during the morning and evening commute hours. It is not uncommon for accidents to occur on this highway, especially during rainy seasons when accidents increase and road closures due to small landslides occur. In both cases, flares are commonly used as a means of providing safety awareness to commuters and redirecting traffic.

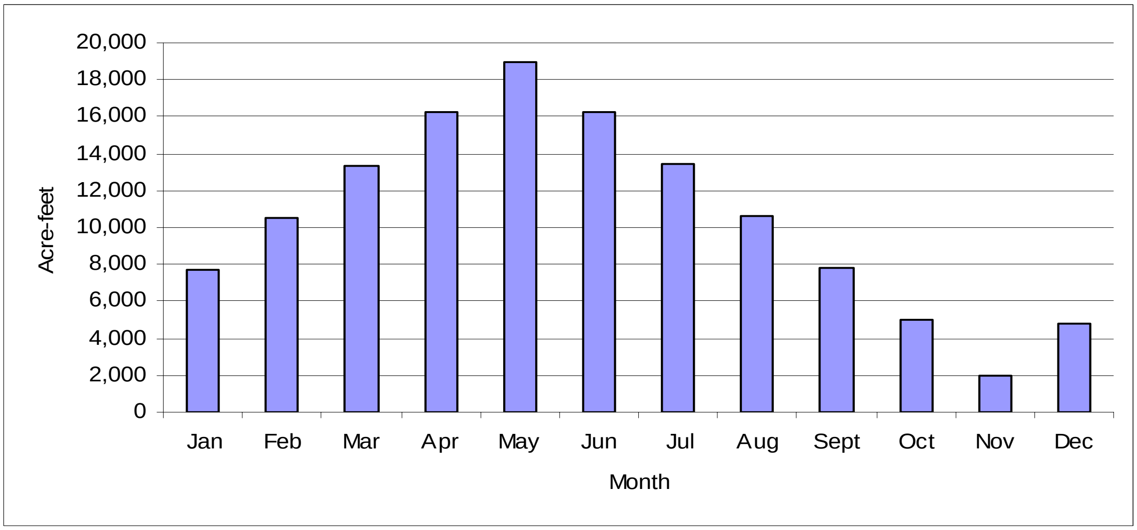
Lexington reservoir is one of ten reservoirs operated by the District for the main purpose of conserving water to recharge the Santa Clara County subbasins through a network of percolation ponds and streamflow infiltration. The reservoir is supplied by the adjoining tributaries and the Los Gatos Creek watershed, of which the District has water rights to 30,000 acre-feet per year (AF/Y). The San Jose Water Company (SJWC) also operates facilities in the Los Gatos Creek watershed including Lake Elsman (south of the reservoir) and several stream diversions which supply the Montevina Water Treatment Plant. The SJWC has water rights to 9,000 AF/Y from the Austrian Dam located at Lake Elsman.



Lexington Reservoir
Figure 1

The annual flows to the reservoir are highly variable with an average inflow of 21,200 AF/Y. Reservoir capacity is 21,400 AF/Y, but due to siltation this volume is decreased to 19,000 AF/Y. Peak flows in wet years have reached three times the capacity of the reservoir, and dry years have produced 1/20 of the reservoir capacity. A simplified graph of average reservoir volumes for a wet-year cycle is illustrated in Figure 2.

Figure 2. Lexington Reservoir Average Volume



The reservoir's main tributary is the Los Gatos Creek, with an approximate contribution from other tributaries in the immediate area surrounding the reservoir of less than 5 % of the total volume during the rainy season. Therefore in a typical wet year, a maximum total runoff volume from the west side runoff areas illustrated in Figure 1, to the reservoir would be approximately 950 ac-ft.

Investigation

In October 2003 the District reported its findings from a controlled laboratory study conducted on the leachability of highway safety flares in water[1]. The tests established in theory that a single 20 minute flare can potentially contaminate up to 2.2 acre-feet of water to just above the notification level of 4 μg/L. Since the study, a new notification level of 6 μg/L has been established by the State of California, this equates to a volume of contaminated water of 1.46 acre-feet. The study also showed that for an unspent flare 51% of the flare's perchlorate mass was dissolved within the first 3.5 hours of contact time.

Based on the notification level and a simple contamination ratio analysis of one unspent flare for every 1.46 ac-ft of water, and a total volume capacity for the Lexington Reservoir of 19,000 ac-ft; a total of approximately 13,000 flares would be necessary to contaminate the reservoir to a perchlorate level of 6 μg/L[2]. Of course this is a worst case scenario, which is not necessarily representative of potential conditions. Therefore, an analysis of how many flares could be used on the section of interest on Highway 17 based on California Highway Patrol (CHP) collisions reports was performed. Topographic and geologic characteristics of the area and reservoir operating levels were also included in the study.

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[1] Perchlorate from Safety Flares A Threat to Water Quality, M. Silva, October 23, 2003.

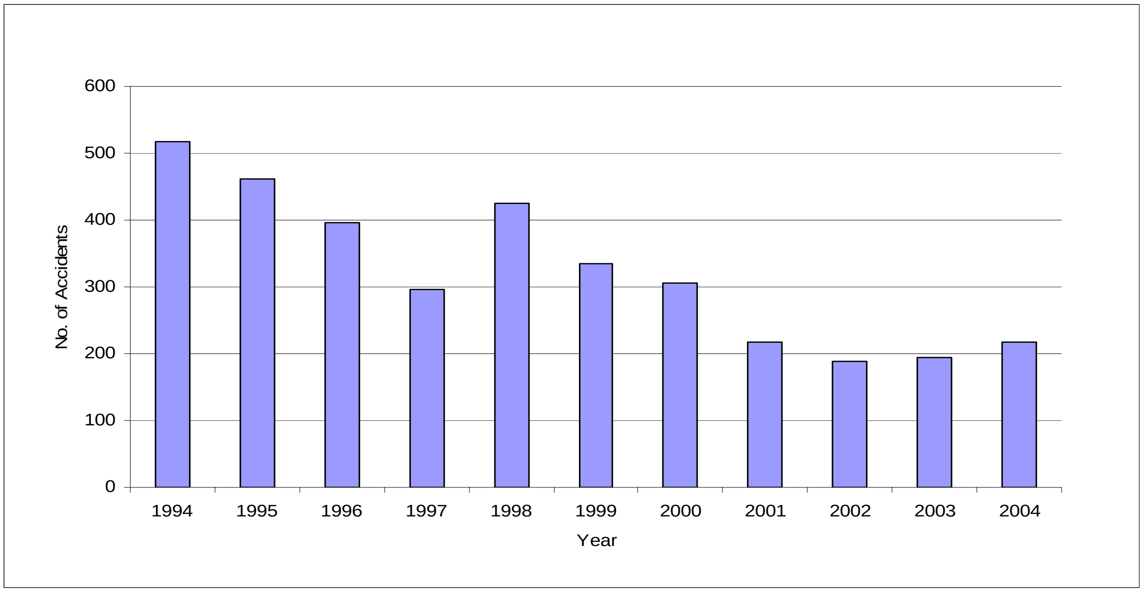
[2] Assumes 100% perchlorate mass mixture of a 20 minute flare composed of 10% potassium perchlorate.

Some of the assumptions made for this evaluation were: All flares and residual flare components left on the road were assumed to be washed away each year with each storm event; Highway sweeping is ineffective in collecting discarded flares left on the road; Runoff from the east side of the reservoir is assumed be negligible compared to that supplied by the west side; and Highway 17 is the only source of flare components in runoff draining to the reservoir.

Accident rate data for Highway 17 was obtained from the Information Services Unit of the Sacramento office of the CHP. As shown in Figure 1, the stretch of Highway 17 covered runs from Saratoga Avenue (Route 9) to Summit Road (Route 35). The accident data covered a period from 1994 through 2004. Based on site topography, the southern 2/3 of this stretch of Highway 17 drains either directly or through tributary creeks to the reservoir. Officer Steve Perea with the San Jose office of the CHP provided a range of flare usage per accident, which is solely based on event conditions and the attending officers' judgment. This rate can range between 3 flares per accident to 20 flares or more per accident.

Generally, total accidents per year since 1994 have been decreasing as shown in Figure 3. In eleven years of available data, the total amount of accidents along this stretch of the highway has decreased by approximately 60%. Monthly accident rates are generally higher during the fall and winter months which coincide with the areas' rainy season (November through May).

Figure 3. Reported Accidents on Highway 17 (between Rte 9 and Route 35)



The period from November through May is when the reservoir typically accumulates 90% of its volume in a wet year. The total reservoir capacity is 19,000 ac-ft/yr, but this volume fluctuates throughout the year as water is released mainly in the spring/summer to supplement the District's groundwater recharge programs.

Figure 2 illustrates how the reservoir reaches its capacity in May and is slowly drawn down during the summer until October when it is kept at approximately 5,000 ac-ft for recreational purposes, and later in November it reaches its lowest volume at 2,000 ac-ft.

The landscape areas surrounding the Lexington reservoir and the stretch of Highway 17 in question are composed of mainly forested terrain, with grades varying between 3 to 1 slopes (horizontal to vertical) and 5 to 1 slopes. The east side of the reservoir is composed of mainly 4 to 1 slopes. Many of the slopes to the west of the reservoir and Highway 17 have grades which divert surface runoff to tributary streams which drain directly to the reservoir; some of these streams are illustrated in Figure 1. Based on the soil conditions and geology for this area[3], soil permeability is low and surface runoff is rapid with the majority of runoff draining uninterrupted to the reservoir.

Information on the existing drainage structures along Highway 17 from Route 9 to Route 35 was obtained from the hydraulics division of Caltrans[4]. Storm water runoff along this stretch of the highway (north bound and south bound) is captured by drainage ditches, catch basins and other structures which drain to the east side of the highway and into tributary creeks or pipes which flow directly to the reservoir. In particular the storm drain inlets along the highway in-between the Alma Fire Station and Old Santa Cruz Highway (Figure 4) were placed there to collect a potential hazardous spill along the highway and divert it to a detention basin just south of the Fire Station. This basin is designed to hold a 2-year 6 hour storm event plus 200,000 gallons of runoff for approximately 4 hours prior to releasing it directly to the reservoir. The outlet is constructed of a 36 inch diameter vertical slotted pipe which is designed to allow solids settlement to occur in the basin while allowing water to drain through the slots. The outlet is plumbed to a junction box with a sliding gate and then runs directly to the reservoir via a hard pipe which travels to Briggs Creek. Other storm drains south of the detention basin up to Route 35 run in a perpendicular direction from the road to the nearest creek on the east side of the highway or stream which feeds into the reservoir.

Discussion

In order to determine if flares posed a viable threat of perchlorate contamination to the reservoir, several sets of data as described above were analyzed. As seen in Figure 2, reservoir volumetric data was plotted against time for a typical wet year to determine when the reservoir is most vulnerable to contamination (at its lowest level) if the estimated quantity of flares came into contact with storm runoff and then flowed to the reservoir.

From this graph three average reservoir levels were established as low, medium and high. These correspond with fall, summer and winter/spring, respectively (Table 1).

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[3] Route 17 at Lexington Reservoir Interchange Project, Final Environmental Impact Statement/Report, Caltrans, July 1993.

[4] Telephone and email communication on 4/29/05 with Monika Pedigo with the Hydraulics Unit of Caltrans.

Table 1. Lexington Reservoir Average Volume (wet year).

Month	Average Volume (ac-ft)	Average volume/season (ac-ft)	Season
Jan	7,666	13,342	Winter/Spring
Feb	10,499		
Mar	13,332		
Apr	16,215		
May	**19,000**		
Jun	16,200	10,600	Summer
Jul	13,400		
Aug	10,600		
Sept	7,800		
Oct	**5,000**		
Nov	**2,000**	3,417	Fall
Dec	4,833		

From these average seasonal levels, an estimate of how many flares were required to come into contact with the runoff reaching the reservoir to contaminate it to a notification level of 6 μg/L[5] was determined. This resulted in the following flare contact quantities[6]:

- Reservoir in the Fall: 2,330 flares
- Reservoir in the Summer: 7,260 flares
- Reservoir in the Winter/Spring: 9,140 flares

To determine how many accidents it would take to achieve these flare contact quantities, two scenarios for flare usage were established, based on a flare usage rate of 3 flares (low) used per accident and 20 flares (high) used per accident. The flare usage rates were then multiplied by the total number of accidents per year to yield an estimated total number of flares used on the highway based on accidents reported (Table 2).

Table 2. Accidents reported by the CHP and estimated flares used.

Year	Total Accidents	Number of flares based on minimum use (3) per total accidents	Number of flares based on maximum use (20) per total accidents
1994	518	1554	10360
1995	461	1383	9220
1996	397	1191	7940
1997	297	891	5940
1998	425	1275	8500
1999	334	1002	6680
2000	306	918	6120
2001	217	651	4340
2002	189	567	3780
2003	194	582	3880
2004	218	654	4360

The mean number of accidents for the eleven year period of record is 323.

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[5] Assuming runoff is the only source of water to the reservoir.

[6] For example: Fall volume 3,400 ac-ft/1.46 ac-ft/flare=2,330flares.

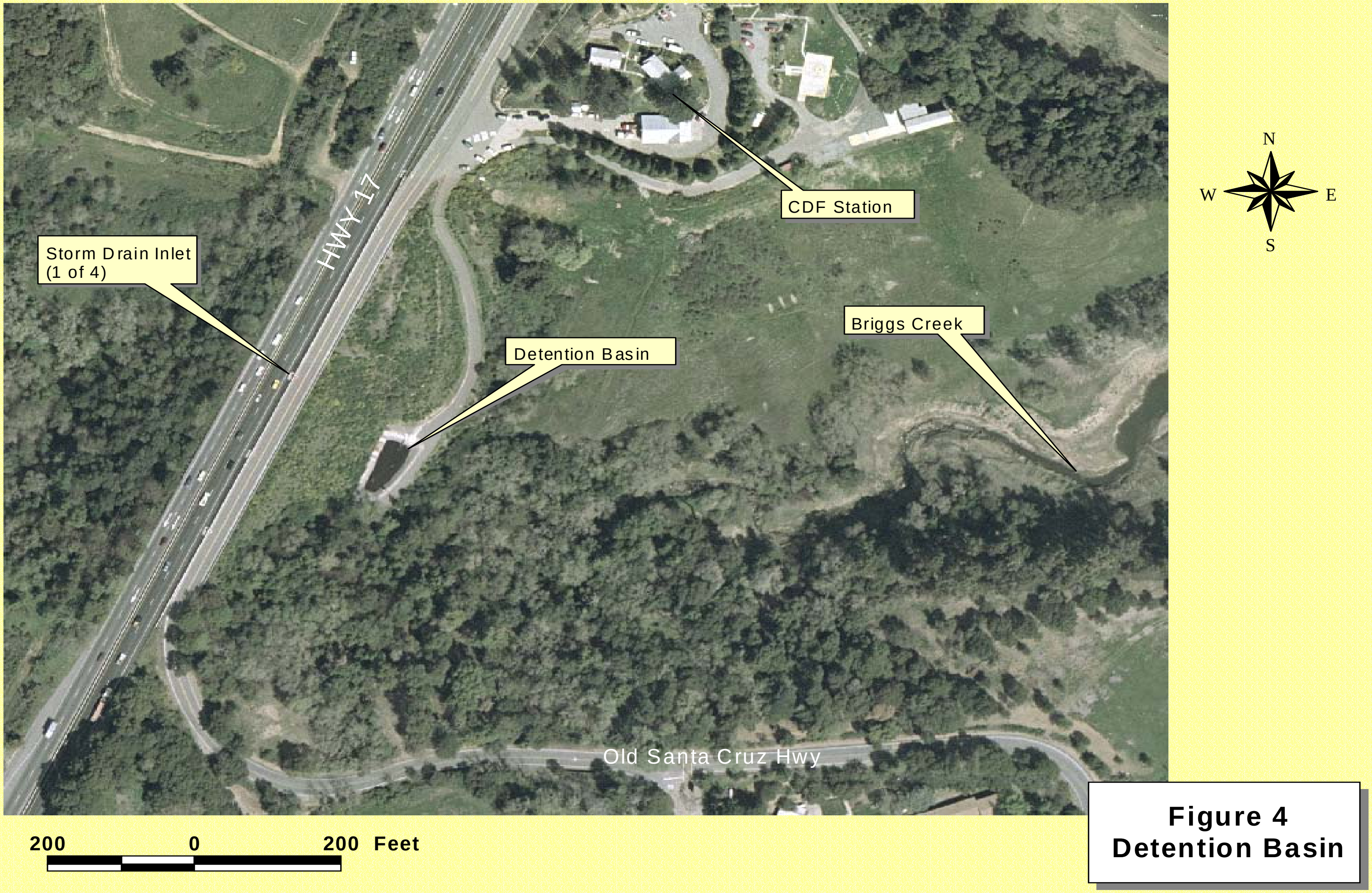


Figure 4
Detention Basin

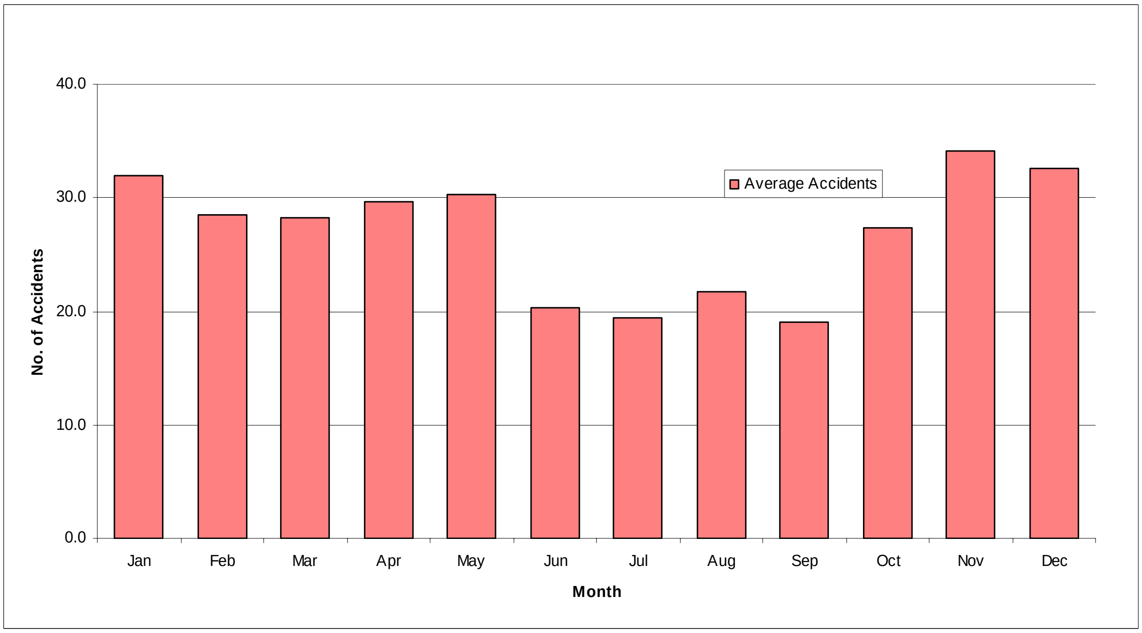
Table 3 indicates theoretically then, for the minimum flare usage rate, it would take 777 accidents and 2,330 flares to reach a perchlorate notification level of 6 μg/L in a reservoir water volume of 3,400 ac-ft. However, as shown in Table 2, the maximum annual number of accidents for the eleven years of record is below this number, and given the eleven year decreasing trend, this is not likely to occur. On the other hand, if the flare usage rate per accident was increased to 20 flares, it would only take 117 accidents to reach the same notification level. In both cases, there is no accounting for additional source water to the reservoir, as explained in the paragraphs ahead.

Table 3: Projected accidents to reach a perchlorate notification level of 6 ppb, based on minimum and maximum flare usage rate per accident of record.

Flare Usage Rate	Average Reservoir Volume (Acre-feet/season) (Column A)	Number of Flares needed to contaminate reservoir volume in Column A to 6 ppb (Column B)	Estimated Number of accidents needed to reach flare quantity in Column B based on flare usage rate
Minimum Flare Usage Rate (3 flares/accident)	3,400	2,330	777
	10,600	7,260	2,420
	13,340	9,140	3,047
Maximum Flare Usage Rate (20 flares/accident)	3,400	2,330	117
	10,600	7,260	363
	13,340	9,140	457

The reservoir's susceptibility to contamination from runoff appears to be greatest during the fall/winter months when the reservoir levels are at the lowest (Figure 2) and it is beginning to fill up with rainfall runoff and Los Gatos Creek source water. In addition, as shown in Figure 5, the average accident rates are higher during these months, and as a result any accumulated flare compounds remaining on the highway are assumed to be washed off the road and into the reservoir.

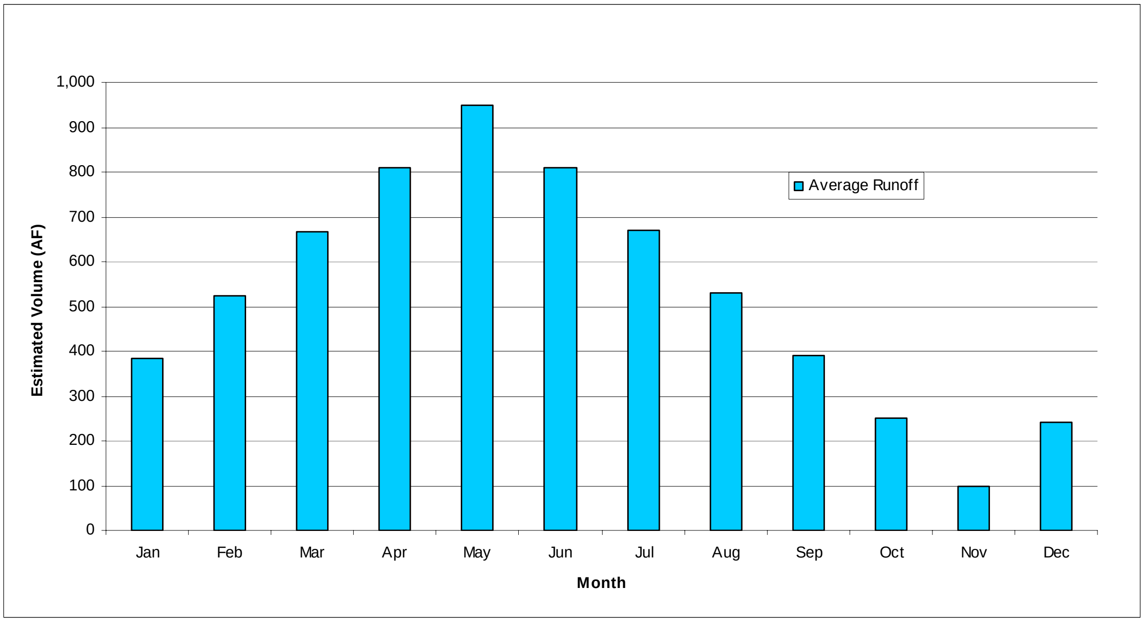
Figure 5. Average Number of Accidents per Month (from 1994 though 2004)



Although this runoff contribution from the west areas adjoining the reservoir is less than 5% of the total peak volume contributed by the Los Gatos Creek, during the first flush (first rains of the season) this minimal contribution could potentially introduce enough contaminated water to present a minimal threat to the reservoir.

The graph below illustrates the contribution of estimated runoff from the west side areas surrounding the reservoir (<5% by volume).

Figure 6. Average Estimated Runoff Volume from Highway 17 between Route 9 and Route 35 (from 1994 through 2004)



During the first flush of the season runoff quantities to the reservoir are estimated between 100 to 700 ac-ft (Figure 6). During this time the average accident rates are between 30 and 35 accidents per month which equates to a maximum flare usage rate between 600 and 700 flares per month. These two factors alone (under a worst case scenario) would equate to a perchlorate concentration in runoff waters ranging between 0.0125 μg/L and 0.088 μg/L, well below the notification level of 6 μg/L.

In addition, since this runoff is not the only source of inflow to the reservoir, and the remaining +/-95% of additional inflow is supplied by the Los Gatos Creek and its tributaries, dilution with this source water would decrease the estimated perchlorate concentration to even further below the notification level (approximately 4.6×10^{-4} μg/L)[7].

Conclusion

Analysis of flare usage and rainfall runoff carrying flare components along Highway 17 and into the Lexington Reservoir appears to indicate that there is a minimal threat of perchlorate contamination to the reservoir. Due to the volume of water inflowing to the reservoir and under a worst case scenario, source water from the main tributary, Los

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[7] Using Mass balance equation $C_1V_1=C_2V_2$, for 19,000 ac-ft, 724 mg/L of ClO_4^- in 15L of water.

Gatos Creek, would essentially dilute any perchlorate concentration in the runoff to levels far below the State notification level.

Although reported accidents for this stretch of the highway are documented, due to the lack of a flare usage protocol per accident by the CHP, it is difficult to determine how many actual flares are used in a given period, much less how many are left unspent, partially spent, swept up by highway maintenance, etc. Topography and highway drainage have been engineered to keep erosion to a minimum, and runoff off the highway and into the adjacent land where it travels mostly unencumbered to local creeks and eventually the reservoir.

Reservoir operating procedures were established to prevent flooding in the area and downstream, and to supply water to the District's recharge facilities. Reservoir water levels in the fall and winter make it vulnerable to contamination from roadway runoff during the first flush of the season, in which other studies have shown that these waters typically contain oil, suspended solids, metals, hydrocarbons and other organics. Without monitoring and testing runoff water and reservoir water, it remains uncertain what effect the inflow from additional source water (Los Gatos Creek) has on diluting these constituents and possibly any perchlorate present.

Recommendations

District Ends Policy E2.1.5 states *"the groundwater basins are aggressively protected from contamination and the threat of contamination."* Due to the uncertainty of what effects any perchlorate concentrations in runoff from the highway can have on the local creeks where highway runoff flows to, taking samples of the first flush at varied locations and in particular at the detention basin shown in Figure 4 would help determine if perchlorate presents any threat. In addition, other common contaminants such as oil, suspended solids, metals, hydrocarbons and other organics could be monitored on a regular basis, while monitoring the water quality to the recharge facilities and meeting our Ends Policy.